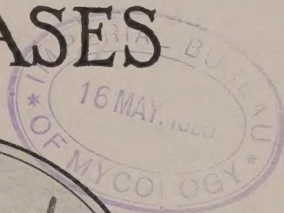


INOCULATION INCREASES



YIELD AND QUALITY OF PEAS FOR CANNING

DIGEST

Inoculation increased the yield of canning peas. Increases occurred in some cases in spite of the previous growing of peas. Page 18

The peas were benefited by inoculation on soils of different fertility. Pages 6, 7, 14, 15, 16

The protein content of the vines was increased by inoculation in ten of the twelve experiments by 11 per cent or more. The increase in protein is a large factor in the feeding value of the vines. (Table V.) Page 23

Inoculation supplies nitrogen from the air with the result that an increased height of vine commonly occurs. The taller vines are more easily harvested. (Table V.) Page 23

Abundant nitrogen produced more vigorous and often more erect vines. Pages 7, 8, 9, 10, 14, 15

The percentages of the number 1's and 2's were decidedly increased by inoculation in the experiments cut at the proper time. This results from prolonging the active growing period. The plants produced more blossoms, more pods and more peas per pod because of retaining this green growing condition longer. (Table I.) Pages 6, 7, 8, 9, 10, 14, 21

Maturity, which is the factor that ruins quality, was delayed by inoculation. This gave more time in which to harvest fancy quality peas. In all cases permitting quality examinations, inoculation improved the grade. Pages 19, 20, 21

Inoculation Increases Yield and Quality of Peas for Canning

A. L. WHITING, E. B. FRED AND J. W. STEVENS

THE YIELD and quality of canning peas can be increased by inoculation. Peas have been grown for several decades in this state, but until recently the need for inoculation and its benefits have not been understood.

Inoculation of Canning Peas---

Increases the yield substantially

Increases the percentage of the smaller sizes of peas

Produces peas of a better quality and a higher protein content

Maintains for a longer time the best condition of the peas in the field

Produces increases in succeeding crops grown on land formerly in peas

Peas are one of the leading cash crops for Wisconsin farmers; and in 1924 over half of the nation's output of canning peas was grown in this state. There were 103,000 acres of peas grown by the 138 factories operating. The industry is expanding rapidly and is becoming popular in the newer parts of the state. The average grower raises between 8 and 10 acres of peas.

In some sections, by reason of repeated growth of the peas on the limestone soils, sufficient inoculation developed to give rise to the erroneous belief that inoculation was not needed in

*During the season of 1924 the effect of inoculation on the yield and quality of peas for canning was studied extensively by the Wisconsin College of Agriculture. Data were obtained from a survey of pea-growing territories, from special field trials, from chemical analysis of peas, vines, and canned samples, and by recognized methods of judging the quality of green peas. Director C. G. Woodbury of the Raw Products Bureau of the National Canners' Association, W. E. Nicholoy of the Wisconsin Pea Packers' Association and numerous canners and farmers gave valuable assistance in carrying out these experiments.

other sections, and that more inoculation on soils having grown peas would not be profitable. Both canners and farmers spread the idea that peas must be grown one year in order to get a good crop the second year, and that not much could be expected of the first crop. The repeated growing of the crop on the same field, however, is an unnecessary and expensive way to inoculate because it can be done so readily by applying cultures to the seed.



Early peas showing effect of inoculation.

Method of Obtaining Results

The yields were taken from five one-square-yard portions on both the uninoculated and inoculated halves. All plants were cut from representative one-square-yard portions of different halves. In one or two cases strips five yards long were taken adjacent to the dividing line, because they afforded the fairest comparison. The weights of the green vines were taken from the five-square-yards, and from these, acre yields were calculated. A more accurate method was employed for obtaining the weights of the peas, number of pods, and percentage distribution. This consisted of taking from each of the above samples, 200 plants, and counting all pods, and the canning-size pods. The total number of peas, the total weight of peas, and the weights of the various sizes were also determined.

The results are probably higher in some cases than those obtained by the grower and canner, as in the method here used no loss in cutting, hulling, vining, grading or weighing occurred, while the canner suffers a loss of 10 to 15 per cent in such processes. In some cases the canner waited from one to seven days after cutting the uninoculated peas before cutting the inoculated peas, and even then obtained more peas of better grade from the inoculated areas.

Inoculation conserves soil nitrogen because the pea bacteria obtain nitrogen from the air, in which there is an inexhaustible supply, and pass it on in suitable forms to the peas.

Grading. The peas after vining were passed through a set of standard sieves. This gave an accurate separation and is what the canner is striving to attain.

Varieties of Peas. Alaska peas are an early variety of smooth peas somewhat like the field pea in growth and color of vines. It was bred especially for canning. It constitutes the major portion of the early peas grown. It usually is ready for canning about two months after planting.

Surprise, Advancer, Perfection, Yellow and Green Admirals, and Horsford are all late wrinkled sweet varieties. They were derived from garden varieties, and usually mature in the order given.

In this bulletin the term fancy is applied to the best quality of peas, extra standard to the next best, and standard to all others. Peas are graded into sizes, number one being the smallest and selling for the highest price, and number two next. Fancy quality may be associated with large sizes, especially with late peas. They do not, however, sell for as high a price as the fancy quality of smaller sizes.

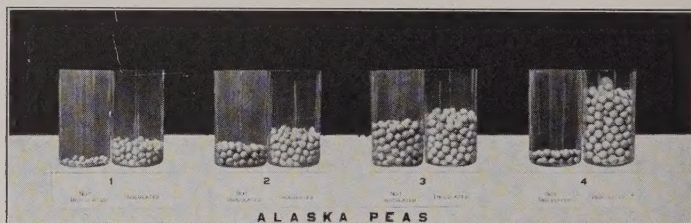
The Experiments and Results

Fields were selected where peas had not grown before, as well as where they had been grown one or more times. The experiments consisted usually of five acres sown with uninoculated seed

which was drilled first, and then five acres sown with inoculated peas. In a few places only three acres of each were planted. Repeated visits were made to the fields, especially as harvest time approached. The experiments were located in seven of the eight pea-growing sections of the state.

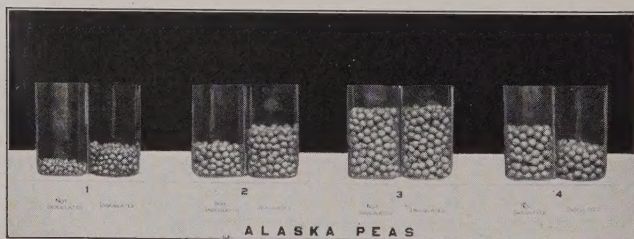
Marked Results Noted

Experiment 1 was located on an acid silt loam field, low in fertility, on which peas had never been grown. About one month after sowing, the inoculated plants were much darker in color than the uninoculated, and in every way appeared much more vigorous. These differences became more prominent as the growing period advanced. The height of the inoculated vines was 23



The increase in the sizes due to inoculation is evident. Had the peas been cut earlier, there would have been an increase in 3's and a decrease in 4's. (Inoculated peas to the right in each pair.)

inches, of the uninoculated 16 inches. No nodules were present on the uninoculated part of the field. The result of the inoculation of the Alaska peas in this trial was a 96 per cent increase in shelled peas, or a gain of about \$25.29 per acre. The yield of vines was increased about 4,000 pounds and the feeding value was also increased.



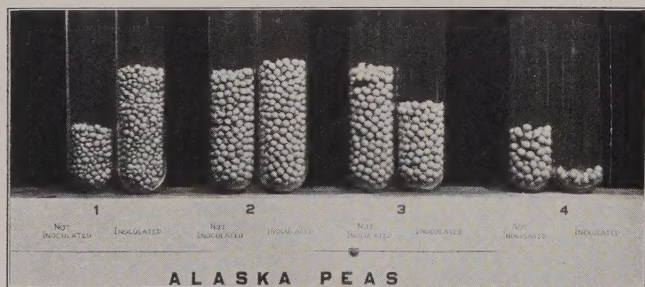
A good increase in 1's and 2's occurred, due to inoculation. A hail storm hurt the peas in this field. (Inoculated peas to the right in each pair.)

Increases Protein Content of the Vines

An acid silt loam soil of medium fertility on which peas had never been grown was used in Experiment 2. The standing crop did not show any variation in color until five days before harvest. A difference in vigor was shown by the height of 25 inches for the inoculated and 19 inches for the uninoculated plants. Nodules were present on the inoculated portion of the field and absent from the uninoculated field. In this trial, inoculation resulted in an increase of only 117 pounds per acre. This increase, however, at 3 cents per pound amounted to \$3.52 per acre. The most marked effects in this trial were an increase of 50 per cent in the protein of the vines and an increase of 15 per cent in the smaller sizes of peas.

Increases Growth of Vines

The field for Experiment 3 was selected because it had grown peas some eleven years before. The year previous to the test, peas were grown on a field adjacent to the uninoculated half. Some cross-working occurred from this field onto the uninocu-



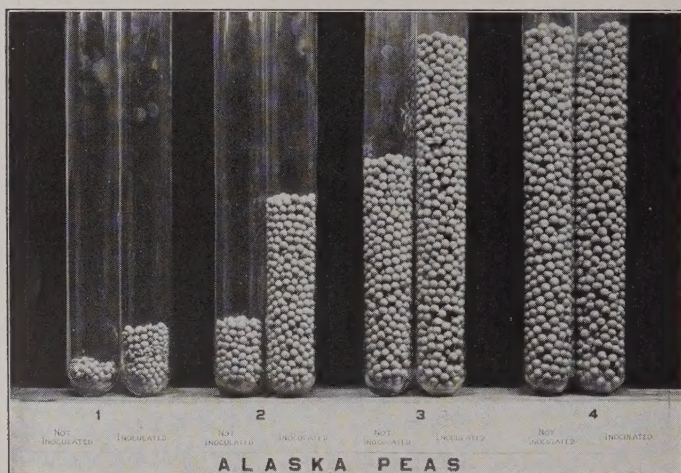
This figure indicates a large gain in 1's and 2's, and is easily recognized as a quality cutting of peas. (Inoculated peas to the right in each pair.)

lated portion of the trial. The result of these conditions was that there were some plants inoculated in this area. The soil was an acid silt loam of medium fertility. The inoculated plants were darker in color, more erect and 5 inches taller than the uninoculated. On account of the natural inoculation present in the soil, it was not to be expected that the inoculation would have much effect. The final results showed no increase in yield of peas, but a 53 per cent increase in weight of vines, and a higher

protein content. There was also a marked effect on the size of the peas, the inoculated portion showing a 22 per cent increase of number one and number two sizes as compared with the uninoculated.

Large Returns Secured

The field in Experiment 4 had two levels which differed by several feet, but this did not affect the comparison as the plots divided the field in a direction opposite to the two levels. Peas had never been grown on the field. The soil, an acid silt loam, was considered very rich because it had been heavily manured

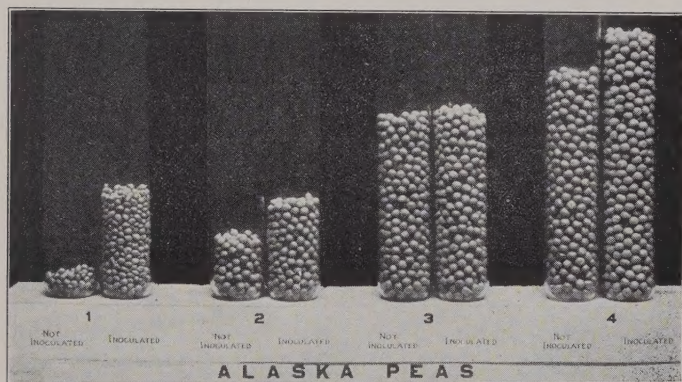


Large increases in yield are seen here, but the quality is not good. An earlier cutting would have greatly improved the quality, and increased the smaller sizes. (Inoculated peas to the right in each pair.)

in past years. The inoculated plants were more vigorous, darker in color, and about eight inches higher than the uninoculated. No nodules were found on the uninoculated portion of the field in Experiment 4. In spite of the high natural fertility of the soil, the inoculation produced an increase of 1,339 pounds of shelled peas per acre or a return at 3 cents per pound of \$40 per acre. The inoculation increased the yield of vines 7,857 pounds per acre, and had a most marked effect on their feeding value as shown by the 35 per cent increase in protein. The grade of the peas as determined by size was also favorably influenced.

Helps Peas on Sandy Lands

An acid sandy loam of low fertility was chosen for Experiment 5. The land responded to liming and appeared to need organic matter badly. At harvest time, the two plots could be easily distinguished from a considerable distance because of the darker green color of the inoculated part. The inoculated plants were more vigorous and were 27 inches high as compared with

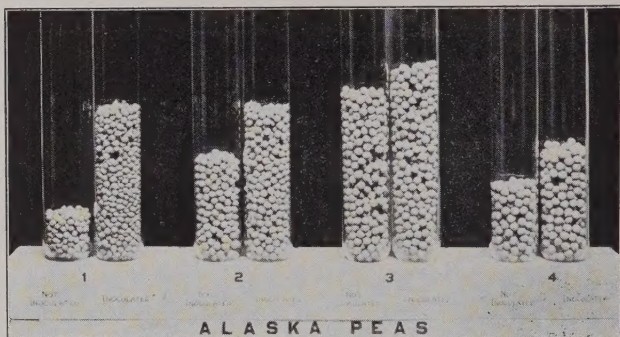


A large gain in total yield and in the percentage gain of 1's and 2's are pictured here. Earlier cutting would have further improved the quality. (Inoculated peas to the right in each pair.)

16 for the uninoculated. There were no nodules on the uninoculated part of the field, while they were present on the inoculated. The presence of nodule bacteria resulted in an increased yield of peas, 680 pounds per acre; of vines, 3,675, and the protein content thereof, 32 per cent. The distribution of peas by size was again influenced in a desirable manner to the extent of an increase of 14 per cent of the smaller sizes.

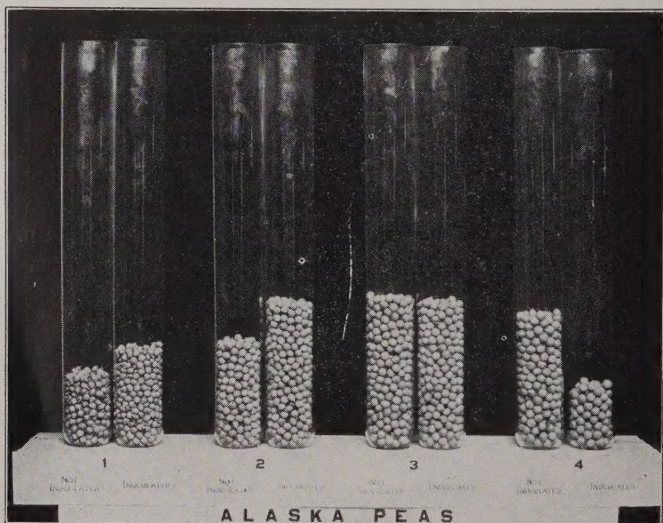
Materially Increases Yield of Vines

The section in which Experiment 6 was located has not been very successful in growing peas in spite of the prevalence of wild vetch. The soil was an acid clay loam of high fertility. In spite of this high fertility there was a marked difference in appearance between the two portions of the field; the inoculated portion was dark green in color while the uninoculated was yel-



A high percentage of 1's and 2's and a high quality are seen here. (Inoculated peas to the right in each pair.)

lowish green. The plants on the inoculated part were 30 inches high as compared with 19 inches on the uninoculated. Nodules were present on the inoculated plants and not on the uninoculated. On this fertile soil 766 pounds of shelled peas per acre were produced by inoculation. The increased financial return for peas

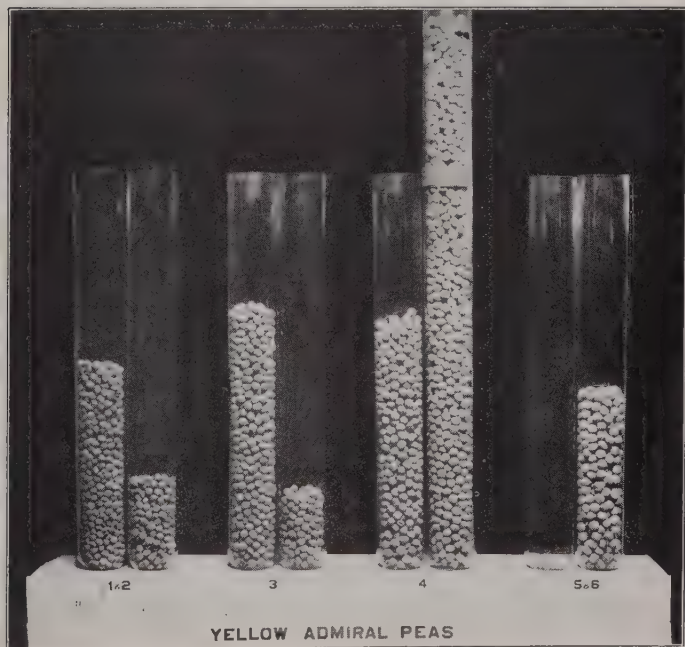


No increase in yield occurred but a better distribution of the sizes was obtained in this quality experiment. (Inoculated peas to the right in each pair.)

amounted to \$23 per acre. The yield of vines was more than doubled and the protein content thereof markedly increased. The increase in number one and number two sizes due to inoculation amounted to 14 per cent.

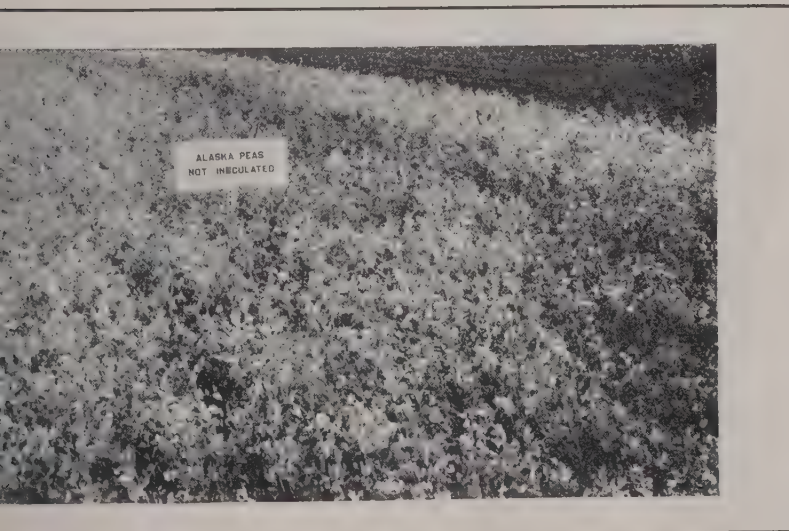
Increases Amount of Smaller Sizes

Unlike the previous test, the field on which Experiment 7 was placed had grown peas four years before and several times previous to that date. The soil was an acid silt loam high in fertility. No differences in the growing crop were visible to an untrained observer. The owner, the fieldmen, and the superintendent of the factory thought that the inoculated plants were a little better than the uninoculated. There was no apparent difference in the number of nodules on the two portions of the field. In this trial the inoculation had no other effect than to favorably influence the percentage of the smaller sizes of peas.



Most excellent quality, and a high yield of the size desired resulted here. The inoculated peas were cut three days after the uninoculated. (Inoculated peas to the right in each pair.)



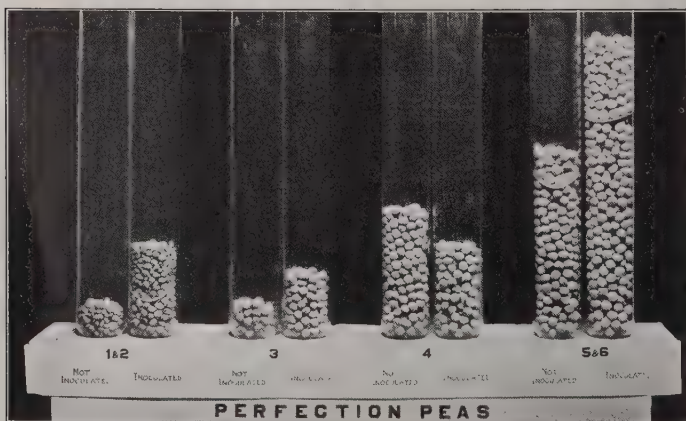


Feeding Value of Vines Increased

For Experiment 8, an acid silt loam soil of high fertility was chosen. The differences in vigor of the two portions of the field were easily visible because of the darker green color of the inoculated plants. The height of the inoculated vines was 50 inches as compared with 39 for the uninoculated. Nodules were absent from the uninoculated portion of the trial. The inoculated Yellow Admiral peas yielded 635 more pounds of shelled peas per acre than the uninoculated. The feeding value of the vines was enhanced and the yield increased 3,429 pounds per acre.

Favorable Effect on Late Peas

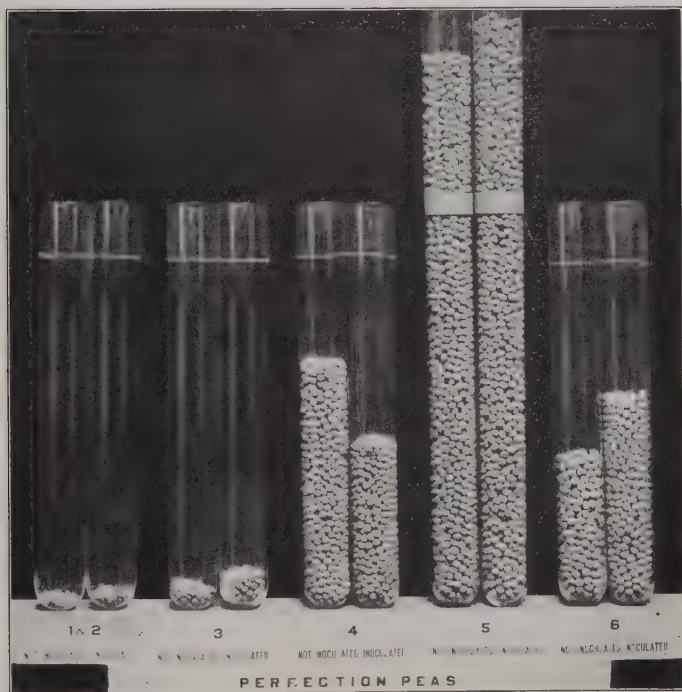
The field of Experiment 9 was planted to Perfection peas. The soil was an acid silt loam of medium fertility. The plots showed the same difference in vigor as mentioned for previous experiments. The differences in color could be seen from considerable distance. The inoculated vines were 17 inches high, the uninoculated ones about 14 inches. Inoculation of this field resulted in an increased return of \$26 per acre for peas. To this must be added the feeding value of approximately 3,600 pounds of vines with an increased protein content of 33 per cent.



A great improvement in quality resulted for inoculation in spite of large sizes produced. (Inoculated peas to the right in each pair.)

Plant Vigor Stimulated

The field of Experiment 10, planted to Perfection peas, had grown peas eleven or twelve years before. The soil was a limestone clay of high fertility. Some parts contained limestone, while in other portions the soil was neutral or very slightly acid. Sufficient bacteria were in the soil to give the uninoculated portion of



A large yield of standard peas of large sizes. Inoculation produced 6 per cent increase in weight. (Inoculated peas to the right in each pair.)

the crop abundant nodules. In spite of this, the inoculation produced a marked difference in the standing crop for the color was darker and the vigor of the plants better. The height of the inoculated plants was 30 inches as compared with 22 for the uninoculated. In spite of abundant natural soil inoculation, the

added bacteria produced 351 pounds of peas per acre, and nearly 4,500 of vines. The grower made a profit of \$10.53 per acre from inoculation.

Difference Less Marked

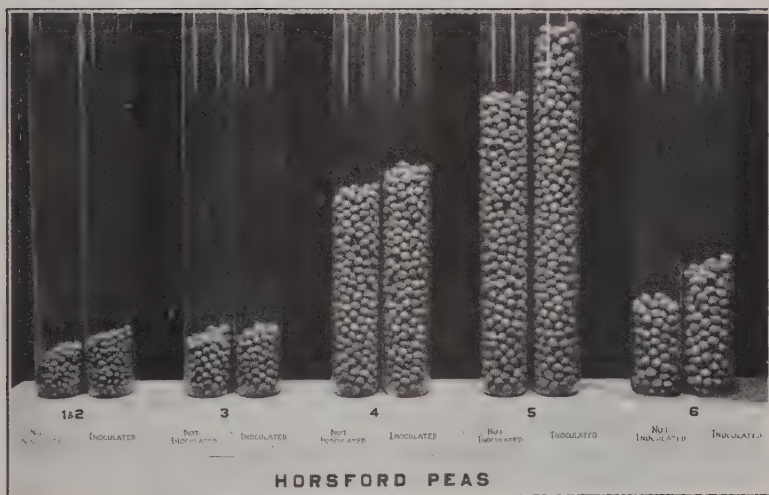
Horsford peas were used in Experiment 11 on a limestone red clay soil high in fertility. Peas had evidently been grown on the land before, as the uninoculated portion of the field showed some nodules. They were, however, less abundant than on the inoculated portion. A difference in color in favor of the inoculated plants was evident at harvest time. The inoculated plants were two inches higher on the average than the uninoculated. The nodule bacteria present in this soil were not sufficient to exert the maximum effect as was shown by an increased yield of 419 pounds of shelled peas per acre, and by 1,516 pounds of vines.

Results Less Noteworthy

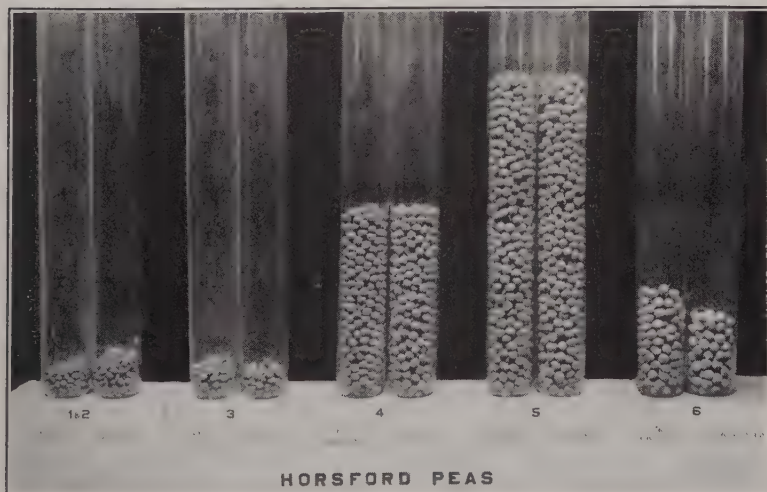
Horsford peas were again grown in Experiment 12 on a limestone sandy loam of medium fertility. The field was very uneven, and the soil of a mixed type. Peas had been grown on the field a few years before. There was no apparent difference in the appearance of the two portions of the field, either as to vigor, color, or abundance of nodules. The plants were of the same height on both portions. The data on yield showed that the cultures had some effect, adding 97 pounds to the harvest of shelled peas and 871 pounds to the vines.

Inoculation on Soils Not Containing Pea Bacteria

The soil of the various experiments was classed as of medium to high fertility with but two exceptions, Experiments 1 and 5. In seven of the experiments, numbers 1, 2, 4, 5, 6, 8, and 9, there were no nodules on the uninoculated plants. In every instance in these trials the inoculated plants showed a greater vigor than the uninoculated, through the darker green color and through an increased height. On the remaining experiments, 3, 7, 10, 11 and 12, there was some natural inoculation in the soil.

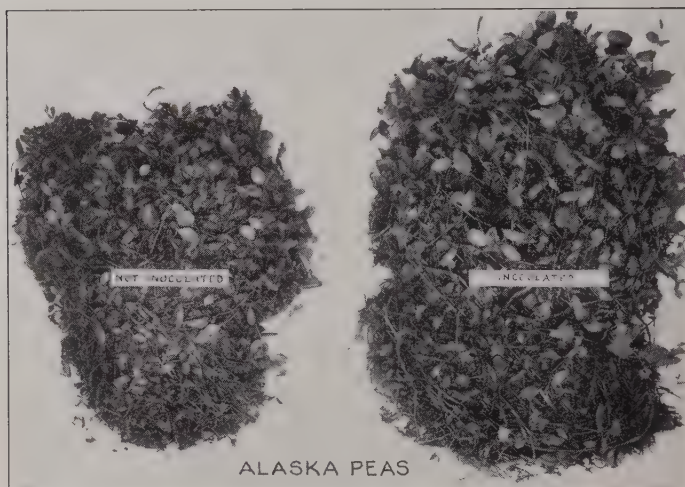


A consistent increase is seen for inoculation. Cutting delayed because of very wet conditions. (Inoculated peas to the right in each pair).



No increase for inoculation as may be judged from the figure. (Inoculated peas to the right in each pair).

In spite of this, differences in the standing crop were apparent in three out of the five cases. In Experiments 7 and 12, no differences were visible in the field.



An increase in weight and height on a field which had grown peas before.

Inoculation on Soils Containing Pea Bacteria

On five of the fields used, Experiments 3, 7, 10, 11 and 12, peas had been grown before, and there were present in the soil, nodule bacteria. In no instance, except possibly in Experiment 7, for which complete data were not collected, were the bacteria which had persisted since the previous crop of peas sufficient to exert the maximum effect. In every case except trials 3 and 7, inoculation gave an increase in yield of shelled peas amounting to from 97 to 419 pounds per acre. In all cases, except in trial 3, the vines were more vigorous, the increase ranging from 871 to 4,489 pounds per acre, and the protein content thereof increased.

Climatic Conditions During Growing Season

Temperature and rainfall are two of the most important agencies that may operate to cause fluctuations in the part played by

nodule bacteria. During April, May and June of 1924, the rainfall was not essentially different from the normal, but in July and August it was above normal, although the temperature was decidedly below. It may be that the low temperature checked



Vines from a field where peas had not grown before.

the activity of the soil bacteria that make soil nitrogen available to plants through the formation of nitrates, and this may in part account for the pronounced effect of inoculation in these experiments. Perhaps the low temperature and consequent low evaporation of soil water resulted in a decrease in available nitrogen, and thus the presence of nodule bacteria proved more helpful to the plants than if the bacterial processes had enabled the peas to draw a larger part of their nitrogen from the soil instead of from the air.

Effect of Inoculation on Quality of Green Peas

The canner wishes to secure as large a percentage as possible of the smaller sizes of peas, since they bring a higher price. If

this increase in percentage of the smaller sizes can be obtained without a decrease in total yield per acre, the advantage is still greater. In a study of the distribution of the sizes it was found that a decided advantage was gained by inoculation in the percentage of the smaller sizes in those experiments that were cut for quality. The results appear in Table I. This effect may go hand in hand with an increase in yield or it may run apart from the yield as in Experiments 3 and 7.



An increase in height and color of vines with a variety producing tall vines.

TABLE I.—EFFECT OF INOCULATION ON SIZES OF PEAS

Experiment number Variety—Alaska	Increase in number one and two sizes
	Per cent
1	-3.4
2	15.5
3	22.0
4	12.4
5	14.2
6	14.1
7	14.8

Other factors than size determine the final quality of the canned product, among these are tenderness and taste. The effect of inoculation on these can not be presented in graphic form. In Experiment 1, the number 3's and 4's from the inoculated plot were placed one grade higher than those from the uninoculated. In Experiment 2 the same was true. In all experiments cut at such a time that the quality could be well judged, the inoculated peas were better than the uninoculated. In not a few cases fancy peas were obtained from the inoculated and extra standard and standard from the uninoculated.

The protein content of the peas was determined in all of the twelve trials in order to learn whether the inoculation exerted an influence in increasing this most valuable constituent of the pea. In Experiments 3, 7, 10, 11 and 12, in which there was some soil inoculation, the effect of the cultures in increasing the protein content of the green peas was small, ranging from no effect to 7.4 per cent increase. In the experiments where no nodules were present on the uninoculated part of the field, the effect of inoculation was much more pronounced, being above 10 per cent in 25 out of 29 comparisons.

Results Indicate Importance of Inoculation

The results seem conclusive that nodule bacteria of peas play an important part in increasing the yield of peas and of vines, as well as decidedly increasing their protein content. The results of the different investigators are in accord on these points. Aside from these favorable effects of inoculation, almost without exception, the presence of the nodule bacteria resulted in a more uniform growth of the plants, a better distribution of sizes, and an improvement in the quality of peas.

TABLE II.—EFFECT OF INOCULATION ON THE YIELD OF GREEN PEAS
AFTER VINING

No. of expt.	Variety of peas	Pounds per acre			Percent- age gain due to inocula- tion	Value of increase at 3 cents per pound
		Inoculated	Un- inoculated	Increase due to in- oculation		
1	Alaska	1717.0	874.0	843.0	96**	\$25.29
2	Alaska	1901.9	1784.5	117.4	7	3.52
3*	Alaska	1760.5	1763.2	—2.7		—08
4	Alaska	4539.2	3200.2	1339.0	42	40.17
5	Alaska	2614.1	1933.4	680.7	35	20.42
6	Alaska	2208.1	1441.5	766.6	53	23.00
7*	Alaska	453.0 ⁽¹⁾	457.5 ⁽¹⁾	—4.5 ⁽⁺⁾		
8	Yellow Adm'l	5012.9	4377.0	635.9	14	19.07
9	Perfection	2729.9	1843.2	886.7	48	26.60
10*	Perfection	6173.7	5822.3	351.4	6	10.53
11*	Horsford	4122.1	3702.6	419.5	11	12.58
12*	Horsford	2911.6	2814.3	97.3	3	2.92

⁽¹⁾ Grams.

*Peas had grown on these fields before.

**Percentages in round numbers.

TABLE III.—EFFECT OF INOCULATION ON THE YIELD OF GREEN VINES
BEFORE VINING

No. of expt.	Variety of peas	Pounds per acre			Percent- age gain due to inocula- tion
		Inoculated	Uninoculated	Increase due to inoculation	
1	Alaska	12,196.8	7,260.0	4,936.8	68**
2	Alaska	17,424.0	15,972.0	1,452.0	9
3*	Alaska	12,584.0	8,228.0	4,356.0	53
4	Alaska	21,780.0	12,584.0	9,196.0	73
5	Alaska	13,552.0	9,196.0	4,356.0	47
6	Alaska	14,036.0	6,776.0	7,260.0	107
7*	Alaska				
8	Yellow Admiral	23,425.6	19,360.0	4,065.6	21
9	Perfection	18,876.0	14,326.4	4,549.6	32
10*	Perfection	23,716.0	18,876.0	4,840.0	26
11*	Horsford	18,150.0	16,214.0	1,936.0	12
12*	Horsford	13,552.0	12,584.0	968.0	8

*Peas had grown on these fields before.

**Percentages in round numbers.

TABLE IV.—EFFECT OF INOCULATION ON PROTEIN CONTENT OF VINES
AFTER VINING
(Water-free basis)

No. of expt.	Variety of peas	Pounds of protein per ton			Percentage gain due to inocula- tion
		Inoculated	Uninoculated	Increase	
1	Alaska	266.2	171.0	95.2	56**
2	Alaska	263.7	176.2	87.5	50
3*	Alaska	315.0	285.0	30.0	11
4	Alaska	237.5	176.1	61.4	35
5	Alaska	283.8	214.5	69.3	32
6	Alaska	329.6	193.8	135.8	70
7*	Alaska	295.0	303.6	—8.6	—3
8	Yellow Admiral	332.0	204.5	127.5	62
9	Perfection	412.2	308.8	103.4	33
10*	Perfection	385.0	325.0	60.0	18
11*	Horsford	386.0	307.5	78.5	26
12*	Horsford	346.0	338.8	7.2	2

*Peas had grown on these fields before.

**Percentages in round numbers.

Some of the more important effects of inoculation on canning peas have been summarized in Table V. The effect of inoculation on the height, yield, and protein content of vines and the yield of green peas, from the twelve experiments is evident from the table.

TABLE V.—SOME OF THE MORE IMPORTANT RESULTS OF INOCULATION
ON CANNING PEAS

No. of expt.	Variety	Increase in height of vines	Increase in yield of vines	Increase in protein of vines	Increase in yield of green peas
		Inches	Per cent	Per cent	Per cent
1	Alaska	7	68	56	96
2	Alaska	6	9	50	7
3*	Alaska	5	53	11	—
4	Alaska	8	73	35	42
5	Alaska	11	47	32	35
6	Alaska	11	107	70	53
7*	Alaska	0	—	—3	—
8	Yellow Admiral	11	21	62	14
9	Perfection	3	32	33	48
10*	Perfection	8	26	18	6
11*	Horsford	2	12	26	11
12*	Horsford	0	8	2	3

*Peas had grown on these fields before.



A darker color and a slight increase in height of a short-vined crop.